ANALYSIS OF THE MAGNITUDE AND FREQUENCY OF THE 4-DAY ANNUAL LOW FLOW AND REGRESSION EQUATIONS FOR ESTIMATING THE 4-DAY, 3-YEAR LOW-FLOW FREQUENCY AT UNGAGED SITES ON UNREGULATED STREAMS IN NEW MEXICO

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 01-4271

Prepared in cooperation with the

NEW MEXICO ENVIRONMENT DEPARTMENT

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By Scott D. Waltemeyer

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U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch	25.40	millimeter
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
cubic foot per second	0.02832	cubic meter per second

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

ANALYSIS OF THE MAGNITUDE AND FREQUENCY OF THE 4-DAY ANNUAL LOW FLOW AND REGRESSION EQUATIONS FOR ESTIMATING THE 4-DAY, 3-YEAR LOW-FLOW FREQUENCY AT UNGAGED SITES ON UNREGULATED STREAMS IN NEW MEXICO

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ABSTRACT

Two regression equations were developed for estimating the 4-day, 3-year (4Q3) low-flow frequency at ungaged sites on unregulated streams in New Mexico. The first, a statewide equation for estimating the 4Q3 low-flow frequency from drainage area and average basin mean winter precipitation, was developed from the data for 50 streamflow-gaging stations that had non-zero 4Q3 low-flow frequency. The 4Q3 low-flow frequency for the 50 gaging stations ranged from 0.08 to 18.7 cubic feet per second. For this statewide equation, the average standard error of estimate was 126 percent and the coefficient of determination was 0.48. The second, an equation for estimating the 4Q3 low-flow frequency in mountainous regions from drainage area, average basin mean winter precipitation, and average basin slope, was developed from the data for 40 gaging stations located above 7,500 feet in elevation. For this regression equation, the average standard error of estimate was 94 percent and the coefficient of determination was 0.66.

A U.S. Geological Survey computer-program interface for a geographical information system (GIS), called the GIS Weasel, was used to determine basin and climatic characteristics for 84 gaging stations that were not affected by regulation. Mean monthly precipitation estimates from 1961 to 1990 were used in the GIS Weasel to compute the climatic characteristics of average basin winter precipitation and annual mean precipitation. The U.S. Geological Survey National Elevation Dataset, which currently consists of the 7.5-minute, 30-meter digital elevation model for each State, was used in the GIS Weasel to compute the basin characteristics of drainage area, average basin slope, average basin elevation, and average basin aspect. Basin and climatic characteristics that were statistically significant in the regression equation with the 4Q3 low-flow frequency were drainage area, which ranged from 1.62 to 5,900 square miles; average basin mean winter precipitation, which ranged from 3.89 to 19.42 inches; and average basin slope, which ranged from 0.166 to 0.517 percent.

INTRODUCTION

Estimates of the magnitude and frequency of annual low flow at ungaged sites on unregulated streams in New Mexico are necessary for the design and administration of water-quality standards. The New Mexico Water Quality Control Commission established the 4-day low-flow frequency having a recurrence interval of 3 years (4Q3) as the daily low flow for these standards. The 4Q3 low-flow frequency is the lowest 4-consecutive-day discharge that has a recurrence interval of 3 years but that does not necessarily occur every 3 years. The New Mexico Environment Department (NMED) is required to use the 4Q3 low flow in the assessment and establishment of Total Maximum Daily Loads (TMDL's) for various water-quality constituents.

The NMED Surface Water Quality Bureau certifies permits for the National Pollutant Discharge Elimination System (NPDES), which is administered by the U.S. Environmental Protection Agency under the Clean Water Act of 1972. The NMED needs streamflow data for NPDES permitting and establishment of TMDL's for both point and nonpoint pollutant sources. The NMED uses the 4Q3 low-flow frequency, which is statistically derived from U.S. Geological Survey (USGS) streamflow-gaging station data, to (1) determine the assimilation capacities of receiving water and (2) use as the minimum discharge at which the New Mexico water-quality standards are applied.

The most recent statistical analysis of streamflow data for New Mexico (Waltemeyer, 1989) provides low-flow frequency characteristics for gaging stations using data through 1985; however, that analysis does not provide regression equations to estimate the 4Q3 low flow at ungaged sites. Currently (2001), the NMED estimates the 4Q3 low-flow frequency for ungaged sites using the methods in Borland (1970). Because of the availability of more streamflow and precipitation data the USGS, in cooperation with the NMED, conducted a study to update the regression equations to estimate the 4Q3 low-flow frequency for ungaged sites on unregulated streams in New Mexico.

Purpose and Scope

This report presents the results of a study to characterize the magnitude and frequency of the 4-day annual low flow for selected streamflow-gaging stations and to develop regional regression equations to estimate the 4Q3 low-flow frequency at ungaged sites on unregulated streams in New Mexico. Two regression equations are presented. For comparison to the 1970 equation, a statewide equation estimates regional 4Q3 low-flow frequency derived from 50 gaging stations that had non-zero flow in all physiographic regions in New Mexico. One equation estimates 4Q3 low-flow frequency for 40 gaging stations in mountainous regions that had non-zero flow. The magnitude and frequency of 4-day annual low-flow characteristics for gaging stations in New Mexico and selected basin, climatic, and low-flow characteristics are presented in tables.

General Physiographic and Hydrologic Setting

The physiography of New Mexico is varied and complex; it includes mountains, plains, plateaus, valleys, and deserts. Precipitation characteristics are the result of physiography, and the corresponding streamflow response in the unregulated reaches of streams is influenced by the precipitation. The State is divided into eight physiographic regions (fig. 1).

The Rocky Mountains (physiographic region 5) create a marked climatological division in the north-central part of the State. Storms that originate in the Pacific Ocean travel over the mountains and progressively intensify in the plains of eastern New Mexico (physiographic regions 1 and 4). Isopluvial contours of annual maximum precipitation intensity indicate a pattern of greater intensity in an easterly direction in the eastern plains (Miller and others, 1973). Storms that originate in the Gulf of Mexico during summer primarily affect the eastern half of New Mexico. Regional thunderstorms typically develop over the mountains during early and late summer. The greatest monthly precipitation, although mostly of irregular regional extent, typically occurs in July and August. For mountainous areas, winter precipitation (October - April) contributes a significant part of the total annual precipitation, which predominately occurs as snowfall.

Intense, convective midsummer storms can result in severe flooding, particularly in the eastern part of the State. Most floods in the northern, southeastern, and southwestern mountainous regions generally result from snowmelt, sometimes from rainfall, and occasionally from rainfall on snowpack. Floods in the plains, plateaus, valleys, and deserts almost always result from rainfall.

Previous Low-Flow Studies

Reiland and Haynes (1963) presented the duration of daily mean discharge and selected sequences of low-mean and high-mean discharge for 122 gaging stations in New Mexico. Their report provided techniques for determining flow-duration data and low- and high-flow frequency data. Borland (1970) presented statewide regression equations based on records for 64 gaging stations. Statewide relations were derived for selected sequences of low- and high-flow frequencies in relation to basin and climatic characteristics. Mean monthly and mean annual discharge relations also were derived. Reiland (1980) presented flow-duration data for 156 gaging stations. Waltemeyer (1989) presented statistical summaries of mean monthly and mean annual flow univariate statistics and low-flow and high-flow frequency and flow-duration information for 169 gaging stations in New Mexico. Records for 17 gaging stations were separated into periods of before, during, and after changes in upstream regulation. The report (Waltemeyer, 1989) had no regional equations based on basin and climatic characteristics.

Low-flow magnitude and frequency are related to basin and climatic characteristics. Low-flow frequency equations have been developed for several States, especially in the Eastern United States (Giese and Mason, 1993); however, streamflow can be more variable in the Western United States than in the east because of the dramatic variations in vegetation and climate. Because of this variability in streamflow, regional equations of low-flow frequency characteristics in relation to basin and climatic characteristics for some physiographic regions of the Western United States have more dispersion in the relations. In some physiographic regions, establishing a statistically significant equation with basin and climatic characteristics can be difficult.

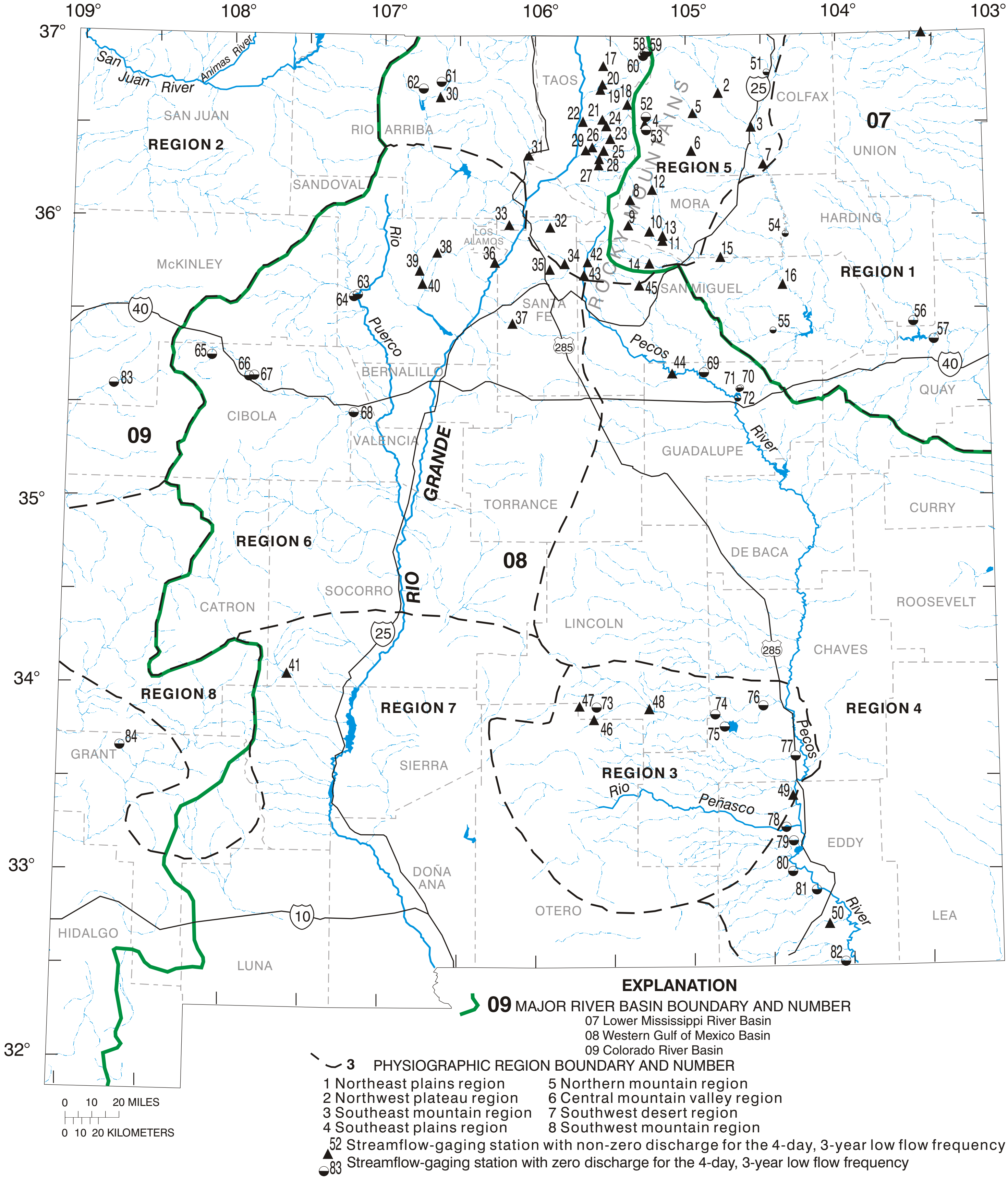

Figure 1. Location of streamflow-gaging stations used for low-flow frequency anaylsis in New Mexico.

A statewide network analysis prepared for New Mexico gaging stations (Borland, 1970) indicated that the 7-day, 2-year low-flow frequency was significantly related to drainage area and mean winter precipitation (1931-60). However, the standard error of estimate (SEE) in Borland's (1970) study was 101 percent. The accuracy of simple- or multiple-regression equations usually is measured by the SEE. The SEE is expressed as a percentage in this report, and it is the standard deviation of the distribution (normal) of residuals about the regression line. For a given regression, about 67 percent of the estimated values will be within one standard deviation of the actual values, and about 95 percent of the estimated values will be within two standard deviations of the actual values. For example, if the SEE of a regression equation is 38 percent, about 67 percent of all values used to develop the regression equations will be within 38 percent of the estimated values and about 95 percent of all values will be within 76 percent of the estimated values or two SEE's.

Acknowledgments

Oregon State University and the Oregon Climatic Service were helpful in providing the precipitation data. Roland Viger, USGS Branch of Regional Research, provided additional programming to the GIS Weasel for determining average basin precipitation.

LOW-FLOW FREQUENCY CHARACTERISTICS

Gaging stations affected by regulation were not considered for this low-flow frequency analysis. The database initially used consisted of streamflow records for 84 continuous-record gaging stations on unregulated streams. The subsequent analysis yielded 50 gaging stations that had non-zero flow for 4 consecutive days in each year of record. Unregulated specifically means that a gaging station is not affected by known regulation such as dams for water storage or flood control. Some gaging stations may have unknown upstream diversions of streamflow.

Streamflow Data

The climatic year was used for this low-flow frequency analysis. In New Mexico, streamflow typically is at its lowest just prior to annual snowmelt runoff. The 1998 climatic year (April 1, 1997, through March 31, 1998) was the last year considered for analysis in this report.

Annual low-flow data characteristics were determined by analyzing the minimum 4-day consecutive low flow of each climatic year for those 84 stations with 10 or more years of record, with the exception of two gaging stations with 6 and 7 years of record. The period of record varies from gaging station to gaging station, but the average length of record was 51 years.

The 50 gaging stations for which the 4Q3 low flow was non-zero (0.08 to 18.7 cubic feet per second) (ft^3/s) are listed in table 1, and the 34 gaging stations that had zero discharge for the 4Q3 low flow are listed in table 2.

Frequency Analysis

The 4-day annual low flows for each station are ranked from smallest to largest for frequency analysis using the log-Pearson type III distribution; a description of the log-Pearson type III distribution is presented in Kite (1977). Other n-day annual low flows commonly used for low-flow frequency analysis include the 1-, 3-, 7-, 14-, 30-, 60-, 90-, 120-, and 183-day flows. The USGS computer program SWSTAT ANNIE (Lumb and others, 1990) was used for the frequency analysis. SWSTAT is available for downloading at *http://water.usgs.gov/software/surface_water.html*, accessed December 14, 2001. The program was used to generate estimated 4-day low flows for selected recurrence intervals ranging from 1.11 to 50 years (tables 1 and 2). An example of the frequency curve is shown in figure 2, which shows the estimated 4Q3 low-flow discharge to be 1 ft^3/s. Basically, the non-exceedance probability is that the lowest 4-day annual low flow in a given year will generally not be less than 1 ft^3/s at least every 3 years. The 4Q3 low flow ranged from 0.08 to 18.7 ft^3/s for 50 gaging stations (table 3). The 4Q3 low flow is the non-exceedance probability that the discharge will be equal to but not be less than the value shown in tables 1 and 2.

Table 1. Four-day annual low flows and years of record used for selected streamflow-gaging stations in New Mexico

Site number (fig. 1)	U.S. Geological Survey gaging-station number	Station name	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and annual non-exceedance probability, in percent								Years of record
			1.11 90%	1.25 80%	2 50%	3 33%	5 20%	10 10%	20 5%	50 2%	
1	07153500	Dry Cimarron River near Guy, N. Mex.	2.14	1.31	0.38	0.14	0.00	0.00	0.00	0.00	31
2	07203000	Vermejo River near Dawson, N. Mex.	4.56	3.01	1.26	.77	.44	.22	.08	.00	82
3	07203525	Vermejo River near Maxwell, N. Mex.	1.33	.92	.28	.10	.02	.00	.00	.00	10
4	07205000	Sixmile Creek near Eagle Nest, N. Mex.	1.00	.62	.26	.17	.12	.08	.06	.04	40
5	07207500	Ponil Creek near Cimarron, N. Mex.	2.43	1.52	.37	.10	.00	.00	.00	.00	82
6	07208500	Rayado Creek at Sauble Ranch near Cimarron, N. Mex.	3.62	3.10	2.20	1.80	1.47	1.16	.94	.74	86
7	07211500	Canadian River near Taylor Springs, N. Mex.	9.80	6.46	1.92	.64	.01	.00	.00	.00	58
8	07214500	Mora River near Holman, N. Mex.	4.26	3.09	1.55	1.04	.69	.44	.29	.18	21
9	07214800	Rio La Casa near Cleveland, N. Mex.	3.29	2.85	2.06	1.68	1.37	1.07	.86	.66	14
10	07215500	Mora River at La Cueva, N. Mex.	5.39	3.68	1.57	.94	.52	.24	.06	.00	92
11	07216500	Mora River near Golondrinas, N. Mex.	6.12	4.08	1.67	.99	.53	.24	.00	.00	83
12	07217100	Coyote Creek above Guadalupita, N. Mex.	2.77	2.10	1.22	.91	.70	.52	.40	.30	18
13	07218000	Coyote Creek near Golondrinas, N. Mex.	2.83	1.87	.80	.50	.32	.19	.12	.07	68
14	07220000	Sapello River at Sapello, N. Mex.	4.14	2.35	.75	.38	.17	.00	.00	.00	57
15	07221000	Mora River near Shoemaker, N. Mex.	6.88	4.54	1.72	.92	.43	.13	.00	.00	76
16	07221500	Canadian River near Sanchez, N. Mex.	18.4	10.1	1.84	.29	.00	.00	.00	.00	85
17	08263000	Latir Creek near Cerro, N. Mex.	2.07	2.00	1.68	1.41	1.13	.82	.60	.38	24
18	08264000	Red River near Red River, N. Mex.	4.22	3.92	3.29	2.94	2.62	2.27	1.99	1.70	20
19	08265000	Red River near Questa, N. Mex.	16.3	13.7	9.37	7.45	5.91	4.50	3.53	2.63	73
20	08266000	Cabresto Creek near Questa, N. Mex.	4.68	4.01	2.92	2.46	2.08	1.72	1.47	1.22	52

Table 1. Four-day annual low flows and years of record used for selected streamflow-gaging stations in New Mexico--Continued

Site number (fig. 1)	U.S. Geological Survey gaging-station number	Station name	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and annual non-exceedance probability, in percent								Years of record
			1.11 90%	1.25 80%	2 50%	3 33%	5 20%	10 10%	20 5%	50 2%	
21	08267500	Rio Hondo near Valdez, N. Mex.	11.3	10.4	8.73	7.90	7.15	6.38	5.78	5.14	63
22	08268500	Arroyo Hondo at Arroyo Hondo, N. Mex.	8.95	7.95	6.46	5.86	5.38	4.93	4.62	4.30	72
23	08269000	Rio Pueblo de Taos near Taos, N. Mex.	7.71	6.84	5.27	4.54	3.90	3.27	2.80	2.33	85
24	08271000	Rio Lucero near Arroyo Seco, N. Mex.	6.43	5.98	5.02	4.49	4.00	3.48	3.06	2.61	85
25	08275000	Rio Fernando de Taos near Taos, N. Mex.	1.22	.67	.22	.12	.07	.04	.02	.01	18
26	08275300	Rio Pueblo de Taos near Ranchito, N. Mex.	9.86	7.06	3.49	2.34	1.58	1.01	.68	.43	24
27	08275500	Rio Grande del Rancho near Talpa, N. Mex.	5.66	5.02	3.74	3.10	2.54	2.00	1.60	1.22	45
28	08275600	Rio Chiquito near Talpa, N. Mex.	2.55	2.18	1.54	1.26	1.03	.81	.65	.51	24
29	08276300	Rio Pueblo de Taos below Los Cordovas, N. Mex.	20.4	16.0	9.66	7.33	5.60	4.14	3.19	2.36	41
30	08284100	Rio Chama near La Puente, N. Mex.	57.4	44.5	25.7	18.7	13.6	9.36	6.76	4.59	42
31	08289000	Rio Ojo Caliente at La Madera, N. Mex.	6.87	5.82	4.01	3.21	2.56	1.96	1.55	1.16	65
32	08291000	Santa Cruz River at Cundiyo, N. Mex.	10.1	8.66	6.45	5.52	4.75	4.03	3.51	2.99	65
33	08292000	Santa Clara Creek near Española, N. Mex.	2.73	2.52	1.61	1.00	.54	.22	.08	.02	62
34	08302200	North Fork Tesuque Creek near Santa Fe, N. Mex.	.46	.44	.39	.37	.35	.33	.31	.30	7
35	08302500	Tesuque Creek above Diversions near Santa Fe, N. Mex.	.99	.87	.60	.46	.34	.24	.17	.11	62
36	08313350	Rito de los Frijoles in Bandelier National Monument, N. Mex.	.88	.76	.53	.43	.34	.26	.20	.14	13
37	08317850	Galisteo Creek above Galisteo Reservoir, N. Mex.	.22	.18	.11	.08	.05	.03	.02	.01	6
38	08321500	Jemez River below East Fork near Jemez Springs, N. Mex.	13.6	11.9	9.35	8.29	7.44	6.63	6.05	5.47	40
39	08323000	Rio Guadalupe at Box Canyon near Jemez, N. Mex.	11.2	9.58	7.06	5.98	5.09	4.25	3.65	3.06	45
40	08324000	Jemez River near Jemez, N. Mex.	22.7	19.6	14.5	12.2	10.4	8.59	7.30	6.04	61

Table 1. Four-day annual low flows and years of record used for selected steamflow-gaging stations in New Mexico--Concluded

Site number (fig. 1)	U.S. Geological Survey gaging-station number	Station name	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and annual non-exceedance probability, in percent: 1.11 90%	1.25 80%	2 50%	3 33%	5 20%	10 10%	20 5%	50 2%	Years of record
41	08360000	Alamosa Creek near Monticello, N. Mex.	6.49	6.28	5.90	5.72	5.57	5.41	5.28	5.15	39
42	08377900	Rio Mora near Terrero, N. Mex.	6.72	5.91	4.41	3.68	3.06	2.45	2.01	1.58	34
43	08378500	Pecos River near Pecos, N. Mex.	28.2	24.7	18.7	15.9	13.6	11.3	9.64	7.97	78
44	08379500	Pecos River near Anton Chico, N. Mex.	16.9	8.89	2.17	.91	.32	.05	.00	.00	86
45	08380500	Gallinas Creek near Montezuma, N. Mex.	4.92	4.02	2.52	1.89	1.41	.99	.72	.49	72
46	08387000	Rio Ruidoso at Hollywood, N. Mex.	10.0	7.36	3.78	2.57	1.75	1.12	.75	.47	44
47	08387600	Eagle Creek below South Fork near Alto, N. Mex.	.46	.38	.19	.10	.04	.00	.00	.00	29
48	08388000	Rio Ruidoso at Hondo, N. Mex.	3.21	1.44	.46	.31	.23	.18	.15	.00	24
49	08396000	Cottonwood Creek near Lake Arthur, N. Mex.	.88	.57	.25	.16	.11	.07	.04	.00	33
50	08405500	Black River above Malaga, N. Mex.	6.34	4.92	3.06	2.40	1.92	1.51	1.24	.99	51

Table 2. Magnitude and frequency of 4-day low-flow characteristics and years of record used for selected streamflow-gaging stations with no flow for the 4-day, 3-year low-flow frequency in New Mexico

Site number (fig. 1)	U.S. Geological Survey gaging-station number	Station name	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and annual non-exceedance probability, in percent								Years of record
			1.11 90%	1.25 80%	2 50%	3 33%	5 20%	10 10%	20 5%	50 2%	
51	07199000	Canadian River near Hebron, N. Mex.	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	39
52	07204000	Moreno Creek at Eagle Nest, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	70
53	07204500	Cieneguilla Creek near Eagle Nest, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	70
54	07214000	Canadian River near Roy, N. Mex.	8.25	3.12	.00	.00	.00	.00	.00	.00	29
55	07222500	Conchas River at Variadero, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	59
56	07226500	Ute Creek near Logan, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	56
57	07227100	Revuelto Creek near Logan, N. Mex.	.17	.08	.00	.00	.00	.00	.00	.00	39
58	08252500	Costilla Creek above Costilla Dam, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	61
59	08253000	Casias Creek near Costilla, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	61
60	08253500	Santistevan Creek near Costilla, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	61
61	08284500	Willow Creek near Park View, N. Mex.	.17	.00	.00	.00	.00	.00	.00	.00	27
62	08284300	Horse Lake Creek above Heron Reservoir near Los Ojos, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	35
63	08340500	Arroyo Chico near Guadalupe, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	42
64	08341300	Bluewater Creek above Bluewater Dam near Bluewater, N. Mex.	.20	.12	.04	.00	.00	.00	.00	.00	10
65	08343500	Rio San Jose near Grants, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	85
66	08343100	Grants Canyon at Grants, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	33
67	08382500	Gallinas River near Colonias, N. Mex.	.25	.00	.00	.00	.00	.00	.00	.00	47
68	08382730	Los Esteros Creek above Santa Rosa Lake, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	24
69	08382760	Los Esteros Creek tributary above Santa Rosa Lake, N. Mex.	.00	.0.0	.00	.00	.00	.00	.00	.00	18
70	08382800	Pecos River above Los Esteros Damsite near Santa Rosa, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	11

Table 2. Magnitude and frequency of 4-day low-flow characteristics and years of record used for selected streamflow-gaging stations with no flow for the 4-day, 3-year low-flow frequency in New Mexico--Concluded

Site number (fig. 1)	U.S. Geological Survey gaging-station number	Station name	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and annual non-exceedance probability, in percent								Years of record
			1.11 90%	1.25 80%	2 50%	3 33%	5 20%	10 10%	20 5%	50 2%	
71	08334000	Rio Puerco above Arroyo Chico near Guadalupe, N. Mex.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	42
72	08351500	Rio San Jose at Correo, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	51
73	08387800	Eagle Creek near Alto, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	11
74	08390500	Rio Hondo at Diamond A Ranch near Roswell, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	58
75	08393200	Rocky Arroyo above Two Rivers Reservoir near Roswell, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	17
76	08393600	North Spring River at Roswell, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	23
77	08394500	Rio Felix at Old Highway Bridge near Hagerman, N. Mex.	.53	.10	.00	.00	.00	.00	.00	.00	47
78	08398500	Rio Peñasco at Dayton, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	47
79	08400000	Fourmile Draw near Lakewood, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	46
80	08401900	Rocky Arroyo at Highway Bridge near Carlsbad, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	34
81	08405150	Dark Canyon Draw at Carlsbad, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	25
82	08408500	Delaware River near Red Bluff, N. Mex.	.52	.03	.00	.00	.00	.00	.00	.00	59
83	09386950	Zuni River above Black Rock Reservoir, N. Mex.	.00	.00	.00	.00	.00	.00	.00	.00	27
84	09430600	Mogollon Creek near Cliff, N. Mex.	.39	.11	.00	.00	.00	.00	.00	.00	30

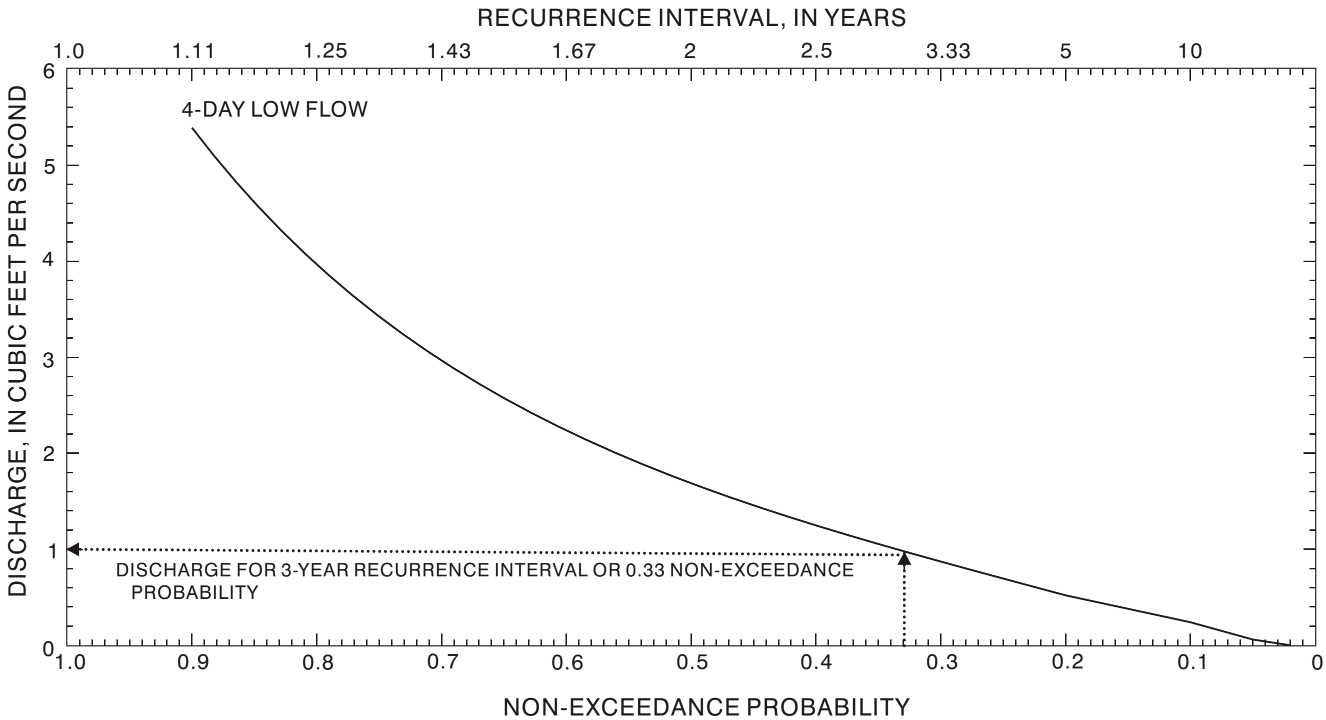

Figure 2. Four-day low-flow frequency curve for streamflow-gaging station 07215500 Mora River at La Cueva, New Mexico. Location of gaging station shown as number 10 in figure 1.

Table 3. Selected basin and climatic characteristics for selected streamflow-gaging stations in New Mexico

[mi^2, square miles; ft^3/s, cubic feet per second; 4Q3, 4-day, 3-year low-flow frequency; Pw, mean winter precipitation (October - April 1961-90); basin and climatic characteristics determined with GIS Weasel]

Site number (fig. 1)	U.S. Geological Survey gaging-station number	Station name	Drainage area (mi^2)	4Q3 (ft^3/s)	Average basin Pw (inches)	Average basin slope (percent)
1	07153500	Dry Cimarron River near Guy, N. Mex.	611	0.14	5.25	0.113
2	07203000	Vermejo River near Dawson, N. Mex.	342	.77	7.80	[1].225
3	07203525	Vermejo River near Maxwell, N. Mex.	548	.10	6.72	[1].195
4	07205000	Sixmile Creek near Eagle Nest, N. Mex.	9.5	.17	7.97	[1].269
5	07207500	Ponil Creek near Cimarron, N. Mex.	183	.10	8.04	[1].250
6	07208500	Rayado Creek at Sauble Ranch near Cimarron, N. Mex.	59.1	1.80	9.68	[1].224
7	07211500	Canadian River near Taylor Springs, N. Mex.	2,760	.64	6.07	.157
8	07214500	Mora River near Holman, N. Mex.	62.7	1.04	11.77	[1].265
9	07214800	Rio la Casa near Cleveland, N. Mex.	22.9	1.68	16.03	[1].309
10	07215500	Mora River at La Cueva, N. Mex.	179	.94	10.17	[1].250
11	07216500	Mora River near Golondrinas, N. Mex.	267	.99	9.10	[1].222
12	07217100	Coyote Creek above Guadalupita, N. Mex.	75.2	.91	8.95	[1].178
13	07218000	Coyote Creek near Golondrinas, N. Mex.	237	.50	6.66	[1].166
14	07220000	Sapello River at Sapello, N. Mex.	132	.38	8.86	[1].218
15	07221000	Mora River near Shoemaker, N. Mex.	1,070	.92	6.69	.140
16	07221500	Canadian River near Sanchez, N. Mex.	5,900	.29	5.58	.127
17	08263000	Latir Creek near Cerro, N. Mex.	10.5	1.41	15.20	[1].396
18	08264000	Red River near Red River, N. Mex.	19.1	2.94	16.83	[1].362
19	08265000	Red River near Questa, N. Mex.	111	7.45	13.85	[1].398
20	08266000	Cabresto Creek near Questa, N. Mex.	35.6	2.46	13.99	[1].408

Table 3. Selected basin and climatic characteristics for selected streamflow-gaging stations in New Mexico--Continued

Site number (fig. 1)	U.S. Geological Survey gaging-station number	Station name	Drainage area (mi^2)	4Q3 (ft^3/s)	Average basin Pw (inches)	Average basin slope (percent)
21	08267500	Rio Hondo near Valdez, N. Mex.	36.7	7.90	13.90	[1]0.517
22	08268500	Arroyo Hondo at Arroyo Hondo, N. Mex.	66.2	5.86	10.77	[1].396
23	08269000	Rio Pueblo de Taos near Taos, N. Mex.	57.5	4.54	12.02	[1].355
24	08271000	Rio Lucero near Arroyo Seco, N. Mex.	16.7	4.49	14.83	[1].506
25	08275000	Rio Fernando de Taos near Taos, N. Mex.	60.3	.12	9.68	[1].283
26	08275300	Rio Pueblo de Taos near Ranchito, N. Mex.	187	2.34	10.20	[1].304
27	08275500	Rio Grande del Rancho near Talpa, N. Mex.	76.2	3.10	15.80	[1].304
28	08275600	Rio Chiquito near Talpa, N. Mex.	37.6	1.26	13.31	[1].312
29	08276300	Rio Pueblo de Taos below Los Cordovas, N. Mex.	384	7.33	10.87	[1].268
30	08284100	Rio Chama near La Puente, N. Mex.	467	18.7	16.96	[1].186
31	08289000	Rio Ojo Caliente at La Madera, N. Mex.	409	3.21	11.22	[1].180
32	08291000	Santa Cruz River at Cundiyo, N. Mex.	91.5	5.52	11.32	[1].359
33	08292000	Santa Clara Creek near Española, N. Mex.	36.5	1.00	11.20	[1].329
34	08302200	North Fork Tesuque Creek near Santa Fe, N. Mex.	1.62	.37	15.26	[1].360
35	08302500	Tesuque Creek above Diversions near Santa Fe, N. Mex.	11.6	.46	9.29	[1].380
36	08313350	Rito de los Frijoles in Bandelier National Monument, N. Mex.	18.3	.43	8.05	[1].279
37	08317850	Galisteo Creek above Galisteo Reservoir, N. Mex.	562	.08	5.31	.097
38	08321500	Jemez River below East Fork near Jemez Springs, N. Mex.	172	8.29	12.76	[1].227
39	08323000	Rio Guadalupe at Box Canyon near Jemez, N. Mex.	233	5.98	13.37	[1].225
40	08324000	Jemez River near Jemez, N. Mex.	467	12.2	12.44	[1].234

Table 3. Selected basin and climatic characteristics for selected streamflow-gaging stations in New Mexico--Concluded

Site number (fig. 1)	U.S. Geological Survey gaging-station number	Station name	Drainage area (mi^2)	4Q3 (ft^3/s)	Average basin Pw (inches)	Average basin slope (percent)
41	08360000	Alamosa Creek near Monticello, N. Mex.	401	5.72	5.16	0.190
42	08377900	Rio Mora near Terrero, N. Mex.	53.2	3.68	19.42	[1].280
43	08378500	Pecos River near Pecos, N. Mex.	170	15.9	17.23	[1].304
44	08379500	Pecos River near Anton Chico, N. Mex.	1,040	.91	7.59	.184
45	08380500	Gallinas Creek near Montezuma, N. Mex.	75.9	1.89	10.89	[1].305
46	08387000	Rio Ruidoso at Hollywood, N. Mex.	120	2.57	8.06	[1].252
47	08387600	Eagle Creek below South Fork near Alto, N. Mex.	8.19	.10	9.15	[1].418
48	08388000	Rio Ruidoso at Hondo, N. Mex.	289	.31	6.63	.245
49	08396000	Cottonwood Creek near Lake Arthur, N. Mex.	201	.16	3.89	.025
50	08405500	Black River above Malaga, N. Mex.	373	2.40	4.21	.162

[1]Mean basin elevation greater than 7,500 feet.

DEVELOPMENT OF REGRESSION EQUATIONS TO ESTIMATE 4-DAY, 3-YEAR LOW FLOW AT UNGAGED SITES

Basin and Climatic Characteristics

Development of Geographical Information System

Basin and climatic characteristics were computed using an ARC/INFO geographical information system (GIS) (ESRI, 1999) and algorithms developed by the USGS. The GIS Weasel (U.S. Geological Survey, 2000) was used to derive basin and climatic characteristics from raster data. GIS Weasel uses a GRID subsystem of ARC/INFO to discretize coverages (vector data) into grids of cells with specific dimensions (for example, 85 feet by 85 feet) and to assign a data value to each grid cell. The grid of data values represents some aspect of the discretized coverage, such as elevation or precipitation. The data values can be manipulated by applying mathematical operations to individual cells, to the whole grid, or by combining two or more grids. GIS Weasel currently (2001) runs on a Unix or Windows NT platform and is available for downloading at *http://wwwbrr.cr.usgs.gov/weasel/*, accessed July 10, 2000.

Coverages of vector data were converted to raster data by discretizing coverages into a regularly spaced grid. The rasterization of the vector data or the use of raster data is herein referred to as "raster modeling." Grid cells were assigned data values representing geospatial characteristics.

Basin Characteristics

The following basin and climatic characteristics were determined with raster modeling using GIS Weasel (tables 3 and 4): drainage area, average basin slope, basin aspect, average basin elevation, average basin mean annual precipitation (1961-90), and average basin mean winter precipitation (1961-90). Existing basin and climatic characteristics also were available from the USGS Water-Data Storage and Retrieval System (WATSTORE) computerized data system (Dempster, 1981; 1983). Existing data values for the following basin and climatic characteristics were obtained from WATSTORE: drainage area, mean annual precipitation (1931-60), basin slope, latitude of gaging station, and channel elevation at 10 and 85 percent of the stream length, in feet (above sea level). These data values were used for preliminary analysis and are not listed in this report.

The National Elevation Dataset (NED) is a USGS raster product (U.S. Geological Survey, 1999) designed to provide national elevation data in a seamless form with a consistent datum, elevation unit, and cartographic projection. Seamless means that all 7.5-minute quadrangles for New Mexico can be compiled into a single coverage or layer. Data corrections were made in the NED assembly process to minimize artifacts, permit edge matching, and fill sliver areas of missing data. The NED has a resolution of 1 arc-second (approximately 30 meters or 91 feet) for the conterminous United States. The New Mexico 7.5-minute, 30-meter NED actual cell size is 28 meters (85 feet). In the NED assembly process, the elevation values were converted to decimal meters as a consistent unit of measure, the North American Datum of 1983 was consistently used as a horizontal datum, and all data were recast in a geographic projection of decimal degrees. The web page describing the NED is currently (2001) available at *http://edcnts12.cr.usgs.gov/ned/default.htm*, accessed July 10, 2000.

The GIS Weasel (U.S. Geological Survey, 2000) was developed to aid in the preparation of spatial information for input to lumped and distributed parameter physical-process models. GIS Weasel provides tools to delineate, characterize, modify, and parameterize "model response units" (MRU's) within a geographical area; in this report the area is the watershed. An MRU in a watershed is typically used to represent an area that is characterized or attributed to predict a uniform physical hydrologic process. Selected basin and climatic characteristics were computed for each watershed (drainage area, average basin slope, average basin elevation, average basin aspect, average basin mean annual precipitation, and average basin mean winter precipitation) using a single MRU for each watershed as shown by the example in figure 3. The 7.5-minute digital elevation models (DEM's) of the NED were used for New Mexico and parts of Colorado. The mean annual and winter precipitation grids were composed for New Mexico and parts of basins that originate in Colorado. A point coverage (latitude and longitude) was developed for the streamflow-gaging station locations listed in table 1.

Drainage area (DA), in square miles, is typically determined by planimetering the delineated area on the largest scale topographic maps available (generally the 7.5-minute quadrangles). In this investigation, DA was determined by raster modeling using 7.5-minute, 30-meter DEM's. Average basin mean winter precipitation

Table 4. Additional basin and climatic characteristics determined using the geographical information system and drainage areas previously published for selected streamflow-gaging stations in New Mexico

[Basin and climatic characteristics determined with GIS Weasel; drainage area, in square miles, determined prior to this investigation]

Site number (fig. 1)	U.S. Geological Survey gaging-station number	Station name	Drainage area (mi^2)	Primary basin aspect (degrees from north)	Average basin elevation (feet above sea level)	Average basin precipitation, 1931-60 (inches)
1	07153500	Dry Cimarron River near Guy, N. Mex.	545	90	6,340	16.88
2	07203000	Vermejo River near Dawson, N. Mex.	301	90	8,100	19.61
3	07203525	Vermejo River near Maxwell, N. Mex.	486	90	7,620	18.48
4	07205000	Sixmile Creek near Eagle Nest, N. Mex.	10.5	135	9,320	18.61
5	07207500	Ponil Creek near Cimarron, N. Mex.	171	90	8,310	19.97
6	07208500	Rayado Creek at Sauble Ranch near Cimarron, N. Mex.	65.0	45	9,630	23.09
7	07211500	Canadian River near Taylor Springs, N. Mex.	2,850	135	7,220	17.98
8	07214500	Mora River near Holman, N. Mex.	57.0	90	9,360	25.87
9	07214800	Rio la Casa near Cleveland, N. Mex.	23.0	45	10,300	33.52
10	07215500	Mora River at La Cueva, N. Mex.	173	90	8,620	24.31
11	07216500	Mora River near Golondrinas, N. Mex.	267	90	8,180	23.02
12	07217100	Coyote Creek above Guadalupita, N. Mex.	71.0	90	9,040	22.49
13	07218000	Coyote Creek near Golondrinas, N. Mex.	215	90	8,060	19.70
14	07220000	Sapello River at Sapello, N. Mex.	132	135	7,800	23.12
15	07221000	Mora River near Shoemaker, N. Mex.	1,100	135	7,380	19.88
16	07221500	Canadian River near Sanchez, N. Mex.	6,020	135	6,780	17.69
17	08263000	Latir Creek near Cerro, N. Mex.	10.5	0	11,100	28.14
18	08264000	Red River near Red River, N. Mex.	19.1	90	11,000	30.63
19	08265000	Red River near Questa, N. Mex.	113	90	10,100	26.72
20	08266000	Cabresto Creek near Questa, N. Mex.	36.7	180	10,300	26.95

Table 4. Additional basin and climatic characteristics determined using the geographical information system and drainage areas previously published for selected streamflow-gaging stations in New Mexico--Continued

Site number (fig. 1)	U.S. Geological Survey gaging-station number	Station name	Drainage area (mi^2)	Primary basin aspect (degrees from north)	Average basin elevation (feet above sea level)	Average basin precipitation, 1931-60 (inches)
21	08267500	Rio Hondo near Valdez, N. Mex.	36.2	225	10,500	25.93
22	08268500	Arroyo Hondo at Arroyo Hondo, N. Mex.	65.6	225	9,530	21.13
23	08269000	Rio Pueblo de Taos near Taos, N. Mex.	66.6	180	9,520	23.40
24	08271000	Rio Lucero near Arroyo Seco, N. Mex.	16.6	180	10,900	27.36
25	08275000	Rio Fernando de Taos near Taos, N. Mex.	71.7	315	9,070	20.58
26	08275300	Rio Pueblo de Taos near Ranchito, N. Mex.	199	225	9,080	20.73
27	08275500	Rio Grande del Rancho near Talpa, N. Mex.	83.0	315	9,410	27.19
28	08275600	Rio Chiquito near Talpa, N. Mex.	37.0	0	9,460	24.80
29	08276300	Rio Pueblo de Taos below Los Cordovas, N. Mex.	380	225	8,870	21.13
30	08284100	Rio Chama near La Puente, N. Mex.	480	225	9,570	32.42
31	08289000	Rio Ojo Caliente at La Madera, N. Mex.	419	90	8,520	19.53
32	08291000	Santa Cruz River at Cundiyo, N. Mex.	86.0	270	9,140	22.02
33	08292000	Santa Clara Creek near Española, N. Mex.	34.5	180	8,830	23.41
34	08302200	North Fork Tesuque Creek near Santa Fe, N. Mex.	1.60	270	10,900	28.96
35	08302500	Tesuque Creek above Diversions near Santa Fe, N. Mex.	11.7	270	8,830	19.61
36	08313350	Rito de los Frijoles in Bandelier National Monument, N. Mex.	17.5	180	7,690	18.98
37	08317850	Galisteo Creek above Galisteo Reservoir, N. Mex.	567	270	6,580	14.07
38	08321500	Jemez River below East Fork near Jemez Springs, N. Mex.	173	270	8,850	25.67
39	08323000	Rio Guadalupe at Box Canyon near Jemez, N. Mex.	235	135	8,520	25.39
40	08324000	Jemez River near Jemez, N. Mex.	470	135	8,570	24.39

Table 4. Additional basin and climatic characteristics determined using the geographical information system and drainage areas previously published for selected streamflow-gaging stations in New Mexico--Concluded

Site number (fig. 1)	U.S. Geological Survey gaging-station number	Station name	Drainage area (mi^2)	Primary basin aspect (degrees from north)	Average basin elevation (feet above sea level)	Average basin precipitation, 1931-60 (inches)
41	08360000	Alamosa Creek near Monticello, N. Mex.	403	135	7,320	15.17
42	08377900	Rio Mora near Terrero, N. Mex.	53.2	315	10,400	38.80
43	08378500	Pecos River near Pecos, N. Mex.	189	270	10,100	33.98
44	08379500	Pecos River near Anton Chico, N. Mex.	1,050	135	7,030	19.15
45	08380500	Gallinas Creek near Montezuma, N. Mex.	84.0	45	8,640	25.85
46	08387000	Rio Ruidoso at Hollywood, N. Mex.	120	45	7,640	23.07
47	08387600	Eagle Creek below South Fork near Alto, N. Mex.	8.14	135	8,560	26.71
48	08388000	Rio Ruidoso at Hondo, N. Mex.	290	45	7,150	20.15
49	08396000	Cottonwood Creek near Lake Arthur, N. Mex.	199	45	3,730	13.24
50	08405500	Black River above Malaga, N. Mex.	343	135	4,080	15.85

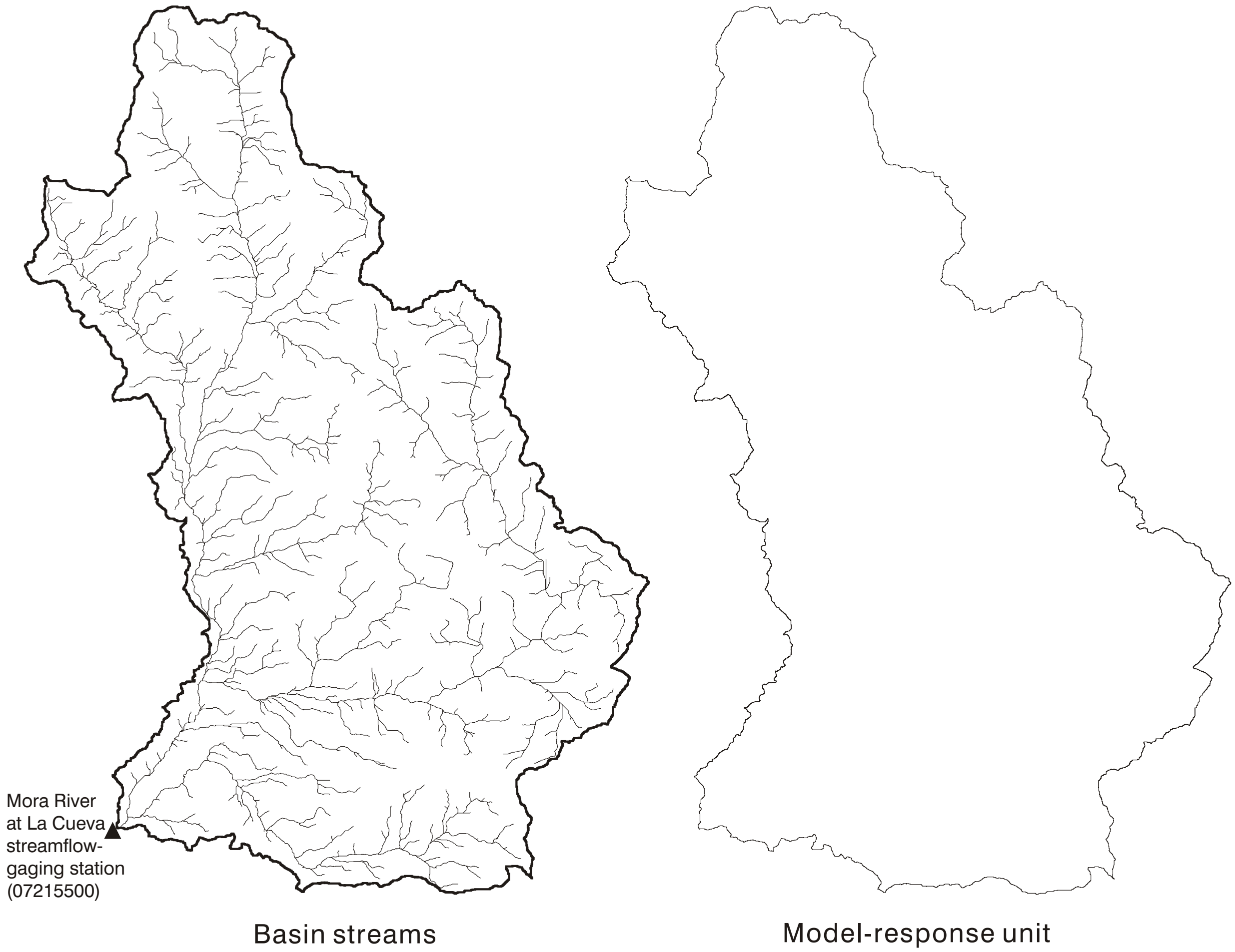

Figure 3. Geographical information system delineation of basin streams and model-response units for Rio Chama near La Puente, New Mexico, streamflow-gaging station (08284100).

(Pw) and average basin mean annual precipitation (Pa) (1961-90, in inches) were averaged for each basin by raster modeling using a 4-kilometer (2.5-mile) grid developed by Daly and others (1998). Average basin slope (S), in percent, was averaged for each basin by raster modeling using the grid cells of the 7.5-minute, 30-meter DEM's. Average basin aspect (A), in degrees from north, was averaged for each basin by raster modeling using the grid cells of the 7.5-minute, 30-meter DEM's. Average basin elevation (E), in feet, was averaged for each basin by raster modeling using the grid cells of the 7.5-minute, 30-meter DEM's.

Climatic Characteristics

Estimates of mean monthly and mean annual precipitation for 1961-90 have been developed for 4-kilometer (2.5-mile) grid cells by Daly and others (1998) using the Parameter-Elevation Regressions on Independent Slopes Model (PRISM) as presented by Daly and others (1994). PRISM estimates are based on all available point data, including the high-elevation precipitation data from Natural Resources Conservation Service data collection, and a DEM to account for the effects of topography through station weighting and simple linear regression of precipitation and elevation. The mean monthly precipitation raster datasets are available at *http://www.ocs.orst.edu/prism/prism_new.html*, accessed November 15, 1999. The raster precipitation data units are in millimeters multiplied by 100, and the geographical coordinates of the grid cells are in decimal degrees.

The mean monthly precipitation (1961-90) raster data were available only by month. By using the 12 monthly values of 30-year mean precipitation for each grid cell, the GRID subsystem of ARC/INFO was used to compute mean values for the annual 12-month period and for the 7-month winter period (October - April). GIS Weasel was then used to compute an average, areally weighted value for each basin from the values for the 4-kilometer (2.5-mile) grid cells within each basin. Finally, total values of precipitation for each period were computed and converted from millimeters to inches by multiplying by the number of months in the period (7 for the winter and 12 for the annual) and dividing by 2,540.

The software system uses a graphical user interface (GUI) based on the ARC/INFO, arc macro language (AML) scripts, and C++ programming language. The operation of the software does not require GIS expertise, but knowledge of ARC/INFO is helpful in changing the geographical projections from decimal degrees to other projections and in merging grids.

Multiple Linear Regression

Multiple-linear regression equations were used to estimate 4Q3 low-flow frequency characteristics for ungaged sites on unregulated streams. An assumption was made that by using separate regression equations for each of the eight physiographic regions in New Mexico (fig. 1), the SEE would decrease in comparison to using one regression equation for the entire State. This assumption was based on prior regression equations developed for physiographic regions in New Mexico (Waltemeyer, 1996). In areas where the 100-year peak discharge was improved by regionalizing, the SEE ranged from 41 to 96 percent for the eight physiographic regions (a decrease from 157 percent using one statewide regression equation) (Waltemeyer, 1996). The greatest decrease in the SEE was expected to be in mountainous regions. Streamflow from the mountainous regions generally is derived from snowmelt runoff where the duration of flow is longer and, thus, low flows are more sustainable. In addition, a more current value for the precipitation variable was desired and used for the regression equations. The mean annual and mean winter precipitation (1961-90) for New Mexico was developed by Daly and others (1998), and these data were used to obtain average basin mean winter precipitation and mean annual precipitation for the 50 gaging stations.

As stated earlier, analysis of the initial 84 gaging stations available for this study indicated that 50 had non-zero 4Q3 low-flow frequencies (table 1) and 34 had 4Q3 low-flow frequency of zero (table 2). Consequently, the gaging station network was insufficient to develop regression equations for low-flow frequency for all physiographic regions in New Mexico. Therefore, development of regression equations was limited to mountainous regions of New Mexico and to the other regions in New Mexico where gaging stations had zero 4Q3 low-flow frequencies.

Results

Regional-regression equations commonly are used to estimate streamflow characteristics at locations where streamflow data are not available. For this study, two equations were developed that relate the 4Q3 low-flow frequency determined at gaging stations to basin and climatic characteristics. Basin and climatic characteristics, derived from GIS Weasel, determined to be significant for inclusion as independent variables in the regression equations were:

DA = drainage area, in square miles;
Pw = average basin mean winter precipitation, in inches; and
S = average basin slope, in percent.

Average basin aspect was not statistically significant in the regression equations, average basin elevation was highly cross correlated with precipitation, and basin mean annual precipitation was cross correlated with basin mean winter precipitation. Average basin mean winter precipitation was used in the regression equations because of its higher correlation coefficient and statistical significance with 4Q3 low-flow frequency. The published drainage area was compared to the drainage area determined in this investigation by GIS Weasel, and the GIS Weasel drainage area had a slightly improved statistical significance and improved overall accuracy in the regression equations. Existing basin and climatic characteristics also were evaluated for statistical significance. Characteristics from the USGS streamflow/basin characteristics file (Dempster, 1981; 1983) (drainage area, average basin elevation, average basin mean annual precipitation, main channel slope, latitude at gaging station, and elevation at 10 and 85 percent of the stream length) were analyzed in the regression equation. Characteristics from the USGS streamflow/basin characteristics file were not used in the final regression equation because of cross correlation or lesser statistical significance.

Ordinary least-squares (OLS) regression techniques were used to determine the most appropriate basin and climatic variables. An OLS multiple-linear regression procedure (Mathsoft, Inc., 1999) was used to determine which independent variables were significant in the two regression equations for the 4Q3 low-flow frequency. The dependent and independent variables were transformed to logarithms (base 10). The general form of the mathematical equation is:

$$\log Q = \log k + a \log x_1 + b \log x_2 + ... + n \log x_n \quad (1)$$

or by taking antilogarithms, the nonlinear form is:

$$Q = k\, x_1^a\, x_2^b ... x_n^n$$

where Q = dependent variable (4Q3 for this report);
k = regression constant;
a,b,...n = regression coefficients; and
$x_1, x_2, ... x_n$ = basin and climatic variables (independent variables).

Drainage area determined using GIS Weasel for the 50 gaging stations that had non-zero discharge for the 4Q3 low-flow frequency ranged from 1.62 to 5,900 square miles (table 3). Average basin mean winter precipitation in these basins ranged from 3.89 to 19.42 inches (table 3). The regression equation developed for the 50 gaging stations in physiographic regions in New Mexico is:

$$4Q3 = 1.2856 \times 10^{-4}\, DA^{0.42}\, P_w^{3.16} \quad (2)$$

where 4Q3 = 4-day, 3-year low-flow frequency, in cubic feet per second;
DA = drainage area, in square miles; and
P_w = average basin mean winter precipitation, 1961-90, in inches.

The average SEE for equation 2 is 126 percent. The coefficient of determination (R^2) is the fraction or proportion of the variance in the 4Q3 low-flow frequency that is explained by the variation of the independent variables in the regression equation. For equation 2, the R^2 is 48 percent. The independent variables were evaluated for inclusion in the regression analysis at the 5-percent level of significance.

An assumption was made that the latitude of a gaging station would help explain the variation in 4Q3 low-flow frequency in the statewide model; however, latitude was not statistically significant. This is largely due to the general lack of data statewide and the reduced database in non-mountainous regions where the 4Q3 low-flow frequency was zero; therefore, the range in latitude is not representative or is not significant.

A regression analysis was conducted for 40 of the 50 streamflow-gaging stations located in mountainous regions with basin elevations greater than 7,500 feet. The assumption was that basins at these locations would be homogenous. The regression equation developed for the mountainous regions provides a more accurate estimate of the 4Q3 low-flow frequency than the statewide regression equation does (eq. 2). For the 40 gaging stations that had a non-zero discharge for the 4Q3 low-flow frequency, drainage area determined using GIS Weasel ranged from 1.62 to 548 square miles (table 3). Average basin mean winter precipitation in these basins ranged from 6.66 to 19.42

inches (table 3). Average basin slope ranged from 0.166 to 0.517 percent (table 3). The regression equation for the mountainous regions of New Mexico is:

$$4Q3 = 7.3287 \times 10^{-5} DA^{0.70} P_w^{3.58} S^{1.35} \qquad (3)$$

The average SEE for this regression equation is 94 percent and the R^2 is 66 percent. For example, the average SEE for a 4Q3 low-flow frequency of 10 ft^3/s ranges from 0.6 to 19.4 ft^3/s at the 95-percent confidence interval.

Use and Limitations

The intended use of regression equations 2 and 3 is to provide reliable estimates of 4Q3 low flow at ungaged sites on unregulated streams in New Mexico. The application of regional equations is not intended to preclude the use of sound hydrologic judgment or any other hydrologic or engineering method that may provide a more reliable estimate. In New Mexico, use of the 4Q3 low-flow frequency regression equations (2 and 3) is limited to perennial streams, mostly in the mountainous regions. The regression equation (eq. 3) defines the 4Q3 low-flow frequency for the mountainous regions and should not be applied elsewhere. Intermittent and ephemeral streams in other mountainous regions of the State had zero flow for the 4Q3 low-flow frequency and thus could not be considered in this analysis. The regression equation for the mountainous regions is intended for perennial streams above 7,500 feet in elevation; thus, it is safe to assume that the 4Q3 for an intermittent or ephemeral stream is zero in all likelihood.

Major rivers in the State have streamflow data from gaging stations, but these stations are mostly regulated; therefore these sites also were not considered for analysis and these data should be used only for the pre-regulation conditions. For sites of interest that are downstream or upstream from a nearby gaging station, the USGS has developed techniques to transfer the data to an ungaged site (Riggs, 1972). In this situation, a partial-record gaging station is established for a discharge relation; thus, the 4Q3 low-flow frequency can be determined to provide an estimate at the partial-record site.

Application of the two regression equations in this report is limited to the range of basin and climatic characteristics used to develop the equations (table 5); application of the regression equations beyond the range of the basin and climatic characteristics listed in table 5 could result in unreliable estimates of the 4Q3 low flow.

Table 5. Ranges of statistically significant basin and climatic characteristics used in the regression analysis

[Pw, average winter precipitation (1961-90); --, data not statistically significant]

Area used in regression analysis	Drainage area (square miles)	Average basin Pw (inches)	Average basin slope (percent)
Mountainous regions	1.62 -548	6.66 -19.42	0.166 -0.517
Statewide	1.62 -5,900	3.89 -19.42	--

SUMMARY

Estimates of the magnitude and frequency of the 4-day annual low flow at ungaged sites on unregulated streams in New Mexico are necessary for the design and administration of water-quality standards. The New Mexico Water Quality Control Commission established the 4Q3 low-flow frequency for those standards. The NMED uses the 4Q3 low-flow frequency for administration of the NPDES and currently for establishment of TMDL’s for watersheds in New Mexico, including both point and nonpoint pollutant sources. Because of the availability of more recent streamflow and precipitation data, the USGS, in cooperation with the NMED, conducted a study to update 4Q3 low-flow frequency characteristics for ungaged sites on unregulated streams in New Mexico.

Two equations were developed for estimating the 4Q3 low-flow frequency: one statewide regression equation estimates 4Q3 low-flow frequency based on data for 50 gaging stations that had non-zero flow in all physiographic regions in New Mexico. The average SEE was 126 percent, and the R^2 was 0.48. The second equation estimates 4Q3 low-flow frequency at 40 gaging stations for mountainous regions greater than 7,500 feet in elevation that had non-zero flow. The average SEE was 94 percent, and the R^2 was 0.66. The regression equations were developed for estimating the magnitude of the 4Q3 low-flow frequency at ungaged sites using data from the start of record through 1998. Eighty-four gaging stations not affected by regulation were available for analysis. The 4Q3 low-flow frequency was zero for 34 gaging stations; thus, 50 gaging stations were used for regression analysis. For the 50 gaging stations, the 4Q3 low-flow frequency ranged from 0.08 to 18.7 ft^3/s.

Basin and climatic characteristics that were statistically significant in relation to the 4Q3 low-flow frequency were drainage area, which ranged from 1.62 to 5,900 square miles; average basin mean winter precipitation, which ranged from 3.89 to 19.42 inches; and average basin slope, which ranged from 0.166 to 0.517 percent. The USGS NED was used in a GIS to determine drainage area and average basin slope. Average basin mean winter precipitation was determined by a GIS using mean winter precipitation for 1961-90.

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